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Typology, Petrology, and Palynology of the Broke Inlet Biface, a Large Flaked Chert Artifact from South-western Australia

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Abstract

The Broke Inlet biface is the largest chert artifact (1797 g) recovered from any prehistoric site in south-western Western Australia. It is an incompletely flaked core taken from shallow water at Broke Inlet, an estuary on the southern coast. Its large size has allowed the preservation of minerals, fossils and textures that are normally destroyed in smaller chert objects such as flakes by weathering or ground-water solution. This makes it a suitable frame of reference for the description of other chert artifacts from the south-west of Western Australia. The chert was formed by silicification of a foraminiferal and bryozoal late Middle or Late Eocene limestone containing apparent sponge spicules and minor pyrite, glauconite, and apparent argillaceous matter. Silicification probably took place shortly after deposition, *i.e.* within the Eocene. On acid digestion, the biface yielded abundant dinoflagellates but no spores or pollen. The dinoflagellate assemblage differs significantly from that in the Dunsborough implement and the Kings Park Formation, and has strong affinities with assemblages from units in the Otway and St. Vincent Basins of south-eastern Australia. The limestone protolith of the chert was probably deposited in water 50-100m deep, in the Eocene sea separating Australia and Antarctica. All evidence indicates that the Plantagenet Group is the provenance of the biface.

Introduction

One of the rocks widely used as raw material for artifacts in south-western Western Australia (see Fig 1) is secondary Eocene chert. There are three significant dates in the history of all such artifacts: the date of sedimentation of the precursor of the chert (the protolith), the date of silicification, and the date of quarrying. Palaeontology (including palynology) can give the first date, and may throw light on the environment of deposition. The time of silicification is more difficult to determine, and can generally only be positioned relative to other events in the diagenetic sequence. However, the world-wide selective silicification of Eocene strata suggests that the silicification was an Eocene process (Gartner 1970): according to McGowran (1989) it reached its peak in the early Middle Eocene. In other words, silicification probably took place during the same geological epoch, and perhaps within the same geological age, as deposition. Quarrying and fashioning of the artifacts was a feature of the prehistoric human occupation of Australia, *i.e.* of the upper Quaternary. Local occupation has been shown to date back 30,000-40,000 years BP (Pearce & Barbetti 1981, Dortch 1984) and may extend further.

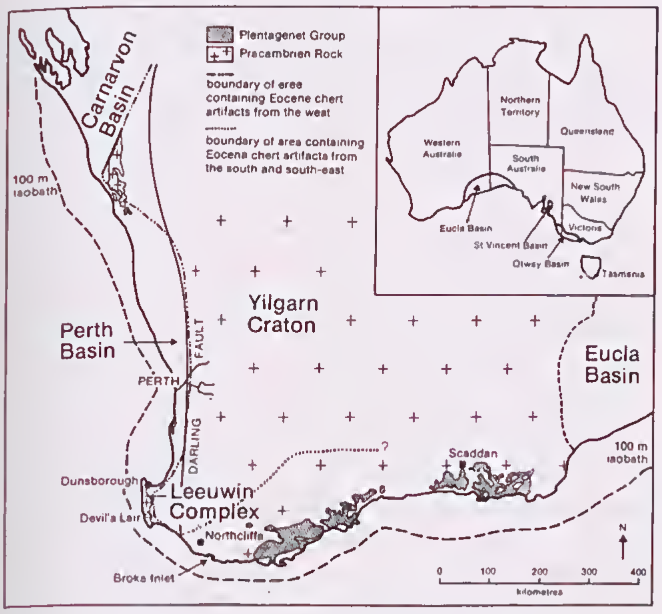

Figure 1. Map showing places referred to in the text.

In south-western Western Australia, the Eocene protoliths of the chert were being deposited in two dissimilar marine environments: the open, generally warm-water area of the eastern Indian Ocean, and the more restricted, probably cooler waters of the widening channel of the southern ocean that had spread between Australia and Antarctica. These chert provenances have been informally labelled the western and south-eastern provenances (Glover 1979). The distribution of exposed strata of the Eocene Plantagenet Group is shown in Hocking (1990).

Eocene chert artifacts on the surface of the Perth Basin and Leeuwin Complex, and the western margin of the Yilgarn Craton, are believed to come from now-submerged formations in the western provenance which were exposed and quarried when sea-level was lower (see Fig 1). Eocene chert artifacts are also found east of the Darling Fault along the southern coast and in its hinterland. Some of the chert from this region is petrologically indistinguishable from the western chert but some contains colloform opal, which is absent from chert found in the west. The opal-bearing chert probably came from the south-eastern provenance comprising onshore Plantagenet Group rocks, and rocks farther south that are now submerged: the accompanying non-opalline chert may have come from the same general area, or possibly from the west. There are many gaps in our knowledge of the geoarchaeology of this provenance.

Some general considerations apply to the study of artifacts from south-western Australia. Palynological assemblages within small artifacts such as flakes are destroyed by weathering , or by percolating solutions, depending on the environment, but they can survive in larger objects such as bifaces. Pyrite and carbonaceous matter persist well in the larger objects, but are destroyed in flakes. Calcite and glauconite are found in some flakes, but have probably been destroyed in many. It follows that studies of the petrology and palynology of large bifaces can make the best contribution to our understanding of the geology of local chert artifacts.

The depositional age of flakes from the western provenance has been indicated from foraminifera and bryozoa (Glover & Cockbain 1971, Quilty 1978), and may be Middle or Late Eocene. The geological age of the Dunsborough implement (also from the western provenance) was shown by pollen (Glover *et al.* 1978) to be Early or Middle Eocene. The typology and archaeological provenance, petrology, and palynology of the Broke Inlet biface are described below, so that it can be fitted into the temporal framework outlined above.

Archaeological Provenance and Typology of the Broke Inlet Biface

The large chert biface illustrated in Fig 2 was collected by one of us (C E D) in shallow water at Broke Inlet, one of the major estuaries along the southern coast of south-western Australia (Fig 1). The find site of this and 24 other Aboriginal stone artifacts and manuports (*i.e.* unmodified stones brought from elsewhere) is near the north-east end of the estuary, about 400m from the north shore. The artifacts were 50 cm underwater on the flat estuary floor, consisting here of unconsolidated white sand, interspersed with patches of dark brown cemented sand. This latter unit appears to be the hardpan of a humus podzol, which is the soil type on the poorly drained sand plain of the estuary's landward margins (Churchward *et al.* 1988: 12, Northcliffe and Deep River-Nornalup Landform and Soil Maps). Very occasional blackboy stumps (*Xanthorrhoea preissii*) are present in growth position in the dark brown cemented sand, which probably pre-dates the estuary's formation at the end of the Flandrian transgression, *c.* 6000 yr BP (Hodgkin & Clark 1989, p.3). Most of the artifacts were lying on the white sand, on what may be a thin lens overlying the cemented sand; others were lying directly on the latter unit, though none was *in situ* in it. It is nevertheless possible that all or some of the artifacts derive from the cemented sand, or from the missing upper horizons of the original soil of which it was presumably part. On the other hand, the assemblage may be largely or entirely attributable to human activities on the estuary floor during times of low water level. Broke Inlet, which is normally a

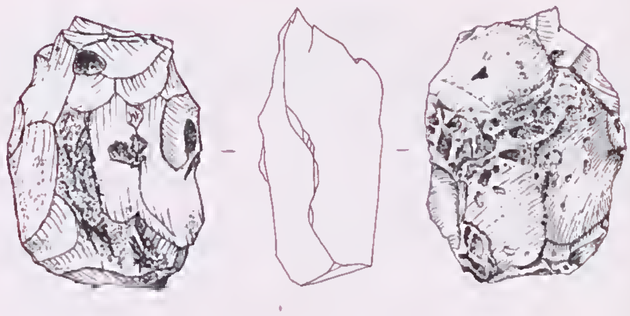

Figure 2. Sketch of Broke Inlet biface.

water body covering 48 km^2, partially dries up during periods of major drought, with its deepest parts remaining as shallow pools surrounded by sand flats.

The artifacts from this site are registered in the Anthropology collection of the Western Australian Museum under the numbers B3879 (the biface and a chert flake) and B3900 (23 other specimens, including quartzite flakes and fragments, pebbles and a percussion / grindstone). The site is numbered S2594 in the registry of the Western Australian Department of Aboriginal Sites. Its geographic position is 34° 56' 15"S, 116° 30' 00"E.

Typological Description

The absence of use-wear or other damage suggestive of use on its edges shows that the Broke Inlet biface is probably not an implement or a tool, but a large core, flaked by direct percussion with a hammerstone to obtain large flakes for use as scraping or cutting tools. The piece is a biface, a category that includes both tools and cores. It is of generalised form, and flaked alternately on its opposing faces. Flake scar facets indicate at least nine major flake removals on its right hand face (see Fig 2), and another six or more flake removals on the opposing face. Unlike the many "exhausted" cores found in archaeological sites, it seems to have been discarded or lost by its knapper at a stage when more large flakes could have been removed from part of both faces. None of the flakes removed from this biface was present in the assemblage, and the only large chert flake collected is of a different petrological facies (see below).

Maximum length of the Broke Inlet biface is 181 mm: its weight is 1797 grams. This is the largest chert artifact known to us from any prehistoric site in the south-west of Western Australia. The original unflaked mass must have been a good deal greater than that of the present biface, which was reduced in size by the removal of large flakes, as shown by the large negative flake scars on parts of both faces, especially some of those in the left-hand view in Fig 2. The larger of these flake scars was struck from a former striking platform which would have been to the right of the right-hand side of the biface, as shown in this view. The weight of the original nodule could easily have been over 3-4 kg. Even if the original nodule had been flaked at its source, the present biface weighing 1797 g would still seem too large to have been carried many km from its place of origin, which may have been either a chert outcrop, or a fluvial or marine deposit incorporating nodules, cherty horizons, or chert clasts.

Archaeological Implications

The Broke Inlet biface is one of several bifacially flaked chert artifacts collected in south-western Australia, and named after their find sites. One of these, known since the 1940's as the Scaddan implement, is considered to be anomalous, and is almost certainly an Acheulian (Lower Palaeolithic) hand axe, judging by its technique, style, surface patination, stone texture, colour and rolled condition. The Scaddan implement analysis concluded that the piece was probably brought from England earlier this century, though a European origin could not be verified by means of petrological and palaeontological examination of its constituent stone (Dortch & Glover 1983).

A second biface, named the Dunsborough implement, was shown to be of Australian origin. Typologically the Broke Inlet biface and the Dunsborough implement are very similar, and the latter is also probably a core, even though it is very much smaller, weighing only 300 g, with a maximum length of 106 mm. The few other bifacially flaked cores made of Eocene chert that have been found at prehistoric sites in south-western Australia are even smaller. Most are discoidal in form and much more delicately flaked than the Broke Inlet and Dunsborough specimens. One Eocene chert biface from the Ellen Brook site *ca* 20 km south of Dunsborough (Fig 1) seems to be a tool rather than a core (Dortch & Glover 1983, Fig 5).

Neither the Broke Inlet biface nor the Dunsborough implement was found in an archaeologically datable context. However, because quarries in Eocene chert were probably inundated by rising seas before about 6000 BP (see Glover 1984), each is likely to be late Pleistocene or Early Holocene in age.

Petrology

Handspecimen

For geological purposes a solid cylindroidal core 4x2.5 cm was drilled into the underside of the specimen: part of it was used for thin-sectioning, and the remainder for the extraction of palynomorphs. The top of the core was retained so that the biface could be restored to its original appearance.

The surface of the specimen where drilled ranges in colour from dark grey (N3) through brownish grey (5YR4/1) and light brown (5YR5/6) to locally very pale orange (10YR8/2) (colours according to Rock-Color Committee, Geological Society of America, 1963). For about 1.5 cm below the surface, the rock is very light grey (N8) changing downward to pinkish grey (5YR8/1) before passing into apparently fresh rock that is irregularly coloured from light grey (N7) to medium grey (N5). In the fresh rock there are three thin (<2mm thick) discontinuous irregular horizons that are locally dark grey (N3). Colour bands are roughly parallel to the extension of the specimen, which in turn is roughly parallel to bedding. Foraminifera and Bryozoa are visible under the hand lens and to the naked eye: where elongate, they are parallel to bedding. Effervescence in dilute HCl is limited to isolated spots.

Thin Section

Under the microscope, the rock can be seen to be a chert made up mainly of a grey opalline matrix, probably with argillaceous impurity, which contains abundant silicified bryozoal, foraminiferal, and other originally calcareous detritus (Fig 3). There are also numerous vaguely defined elongate grains up to about 0.5mm long that are probably sponge spicules.

Foraminiferal shell walls are well defined: they consist mainly of fine-grained quartz or chalcedony. Some chambers are filled or partly filled with grey opal, but most are filled with coarse chalcedony. Less commonly, chambers are filled with a brown isotropic mineral resembling opal, but of uncertain composition: the material may consist of matrix that has been only partly silicified. The inner walls of fossil chambers containing chalcedony are commonly outlined by a fringe of roughly wedge-shaped objects, commonly about 0.01mm long, with pronounced negative relief that causes them to appear dark grey to black under low magnification. The objects are rare in chambers filled with opal, and they make up <1% of the rock. Examination under the scanning electron microscope reveals that the objects are cavities. Other material which makes up <5% of the rock includes minute dark fragments that are probably carbonaceous, pyrite framboids that are brassy in reflected light, green grains showing the aggregate polarisation typical of glauconite, and small isolated patches of calcite. Close to the artifact surface there are pale brown spots of limonite.

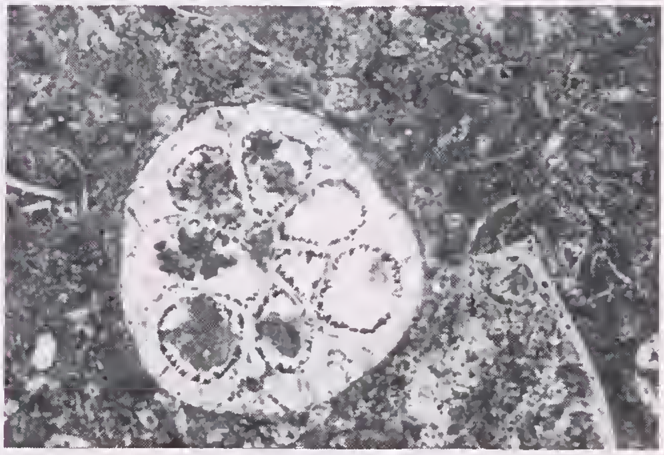

Figure 3. Photomicrograph of chert from Broke Inlet biface showing cross-section of bryozoan (mainly white) set in a grey matrix of impure, probably argillaceous opal. The walls of the bryozoan are composed of fine chalcedony (white), and the chambers are filled with coarser chalcedony (white) and opal (grey). Note the well-defined fringe of dark, wedge-shaped cavities on the chamber walls. The light-coloured objects in the grey matrix are fossil debris, mainly spicules, and the dark patches contain limonite. Plane-polarised light. Width of field 1.35 mm.

Petrological interpretation

The chert is a silicified impure limestone in which the forms of silica reflect most of the original fabric. Quartz and chalcedony replace shell walls, impure opal substitutes for the argillaceous and calcareous matrix, and chalcedony occupies chambers that may have been largely empty before silicification. As usual in Western Australian secondary Eocene chert, glauconite has not been altered to silica. The framboids of pyrite described here are absent from chert flakes, because the smaller size of the flakes allows the penetration of oxidising fluids.

The minute, inwardly directed wedge-shaped cavities forming dark inner fringes to many of the chambers are common in Western Australian artifacts of Eocene chert and have been noted in previous petrological descriptions (Glover 1975, Glover *et al.* 1978). The cavities probably formed by the dissolution of a fringe of crystals (perhaps carbonate) growing into the centre of the chambers from the walls. If so, the mineral apparently never filled the cavities, because the successful crystals would have increased in diameter inwardly, to give the classic drusy carbonate fabric. The chalcedonic filling, on the other hand, has an irregular texture, and may have been formed from silica gel that filled the remaining space. A hypothetical diagenetic sequence that would account for the observed texture is as follows: a fringe or lining of calcite grows on the inner surface of the shell, and is followed by silica gel which fills the remaining space and converts to chalcedony and quartz, after which the calcite forming the fringe dissolves. Probably at about the same time, clay-carbonate matrix is converted to impure opal, and shells are silicified.

The palimpsest (ghost) fabric allows reconstruction of the original rock as a fossiliferous, impure limestone or, more precisely, a foraminiferal, bryozoal, and spicular lime wackestone containing minor glauconite, pyrite, and carbonaceous material, and probably clay minerals (classification of Dunham 1962).

Foraminiferal Palaeontology

Foraminifera are best studied after extraction from sedimentary rock, a process not possible with chert. The silicified foraminifera observed here in thin section consist of smaller benthonic rotaliids and very small planktonic forms. The foraminifers *Subbotina*, a very small spinose *Acarinina*, and possible primitive *Turborotalia cerroazulensis* suggest middle Eocene age (D W Haig, pers. comm.). The biota indicate a mid-neritic (50-100m) depth of deposition for the limestone.

Palynology

The dinoflagellate assemblage

Two separate extractions of acid-insoluble organic matter were undertaken from chips of the artifact to provide adequate material for palynological analysis. The extracts are small but similar in composition, indicating that they indeed represent *in situ* assemblages with no laboratory contamination.

The organic extract consists primarily of dinoflagellates (marine microplankton) and sapropel, with lesser amounts of carbonaceous material. Not a single spore or pollen was observed, and plant cuticular material was rare. This is evidence of a marine depositional environment with negligible terrestrial input. The following dinoflagellate species, several of them undescribed, were identified. Some key forms are illustrated in Figure 4.

Aireiana verrucosa Cookson & Eisenack 1965 - Figure 4 J,K

Batiacasphaera sp.

Circulodinium? sp. - Figure 4 A,B

Cleistosphaeridium spp.

Cordosphaeridium inodes (Klumpp 1953) Eisenack 1963

Cordosphaeridium sp.

Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978 - Figure 4 L,M

Deflandrea sp.

Fibrocysta sp. - Figure 4 H,I

Gen. et sp. indet. - Figure 4 G

Homotryblium floripes (Deflandre & Cookson 1955) Stover 1975 - Figure 4 D

Impagidinium victorianum (Cookson & Eisenack 1965) Stover & Evitt 1978 - Figure 4 E,F

Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967

Operculodinium sp.

Spiniferites spp.

Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969

cf. *Systematophora* sp.

Tectatodinium pellitum Wall 1967 - Figure 4 C

Fibrocysta sp. and *Tectatodinium pellitum* are common in the sample, with *Circulodinium*? sp. and *Homotryblium floripes* next in abundance.

Provenance, age, and correlation

The presence in the sample of *Aireiana verrucosa*, whose only previously published records are from south-eastern Australia, is consistent with the sample being of Australian rather than of foreign origin. *A. verrucosa* has been recorded from the Otway Basin in Victoria (Cookson & Eisenack 1965, Stover 1975) and the St. Vincent Basin in South Australia (Harris 1985).

The age of the chert dinoflagellate assemblage can be addressed by correlation with Eocene dinoflagellate assemblage zones erected for south-eastern Australia by Harris (1985). This zonation built on earlier work by Partridge (1976) and can be compared with the New Zealand zonation of Wilson (1984, 1985).

The chert dinoflagellate assemblage correlates unequivocally with the *Corrudinium incompositum* zone of Harris (1985). That zone is dated by correlation with the planktonic foraminiferal zones proposed by Berggren (1969) and the spore-pollen zonations of Harris (1971) and Stover & Partridge (1973) as latest Middle to Late Eocene (Harris 1985). Marshall and Partridge (1988, p.242 and fig 4) imply that the *C. incompositum* zone is entirely Late Eocene in age.

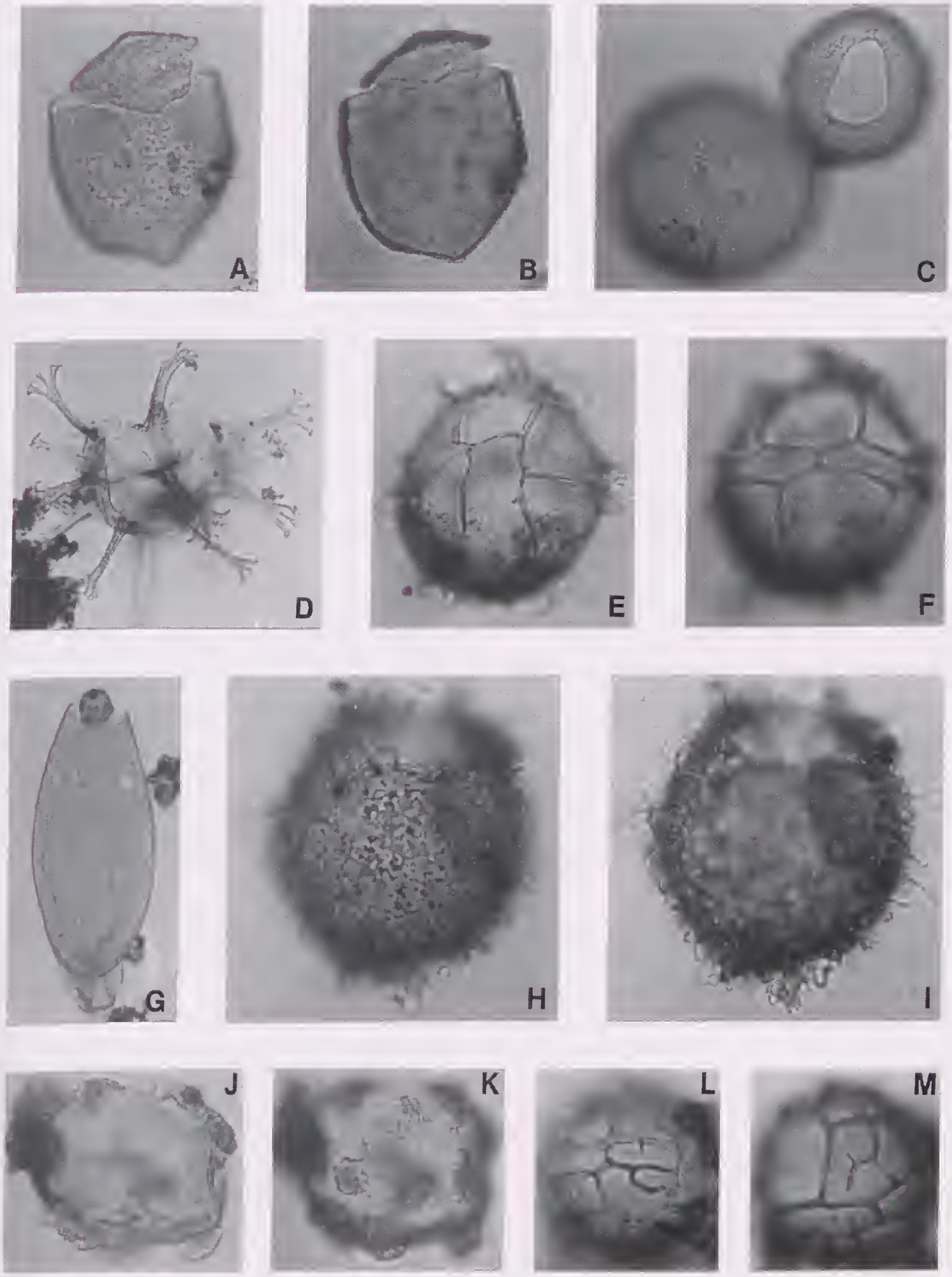

Figure 4. Dinoflagellates from the Broke Inlet biface; all magnified X500 except L,M X1000. A,B, *Circulodinium?* sp., ventral view, high and intermediate focus; C, *Tectatodinium pellitum*, two specimens; D, *Homotryblium floripes*; E,F, *Impagidinium victorianum*, ventral view, high and low focus; G, Gen. et sp. indet.; H,I, *Fibrocysta* sp., dorsal view, high and intermediate focus; J,K *Aireiana verrucosa*, high and low focus; L,M, *Corrudinium incompositum*, right lateral view, high and low focus.

Zonal indicators extracted from the chert include *Corrudinium incompositum*, which typifies the zone, and *Aireiana verrucosa*, which makes its first stratigraphic appearance in the zone, and is restricted to the Late Eocene. *C. incompositum* was first described from the Oligocene of the Gulf Coast, U.S.A. (Drugg 1970), but in Australia is restricted to the Late Eocene (and possibly the late Middle Eocene). It has been recorded from the Gippsland Basin (Marshall & Partridge, 1988), the Otway Basin (A D Partridge, pers. comm.), the St. Vincent Basin (Harris, 1985), and the eastern Eucla Basin (Benbow *et al.* 1982). *A. verrucosa* has been reported from the Otway Basin (Cookson & Eisenack 1965, Stover 1975), and the St. Vincent Basin (Harris 1985).

Other age-diagnostic species include *Tectatodinium pellitum*, *Homotryblium floripes*, *Systematophora placacantha* and *Impagidinium victorianum*. The first three species are widely occurring, with each having an oldest occurrence of Middle Eocene. *I. victorianum* has been reported from Middle to Late Eocene sediments offshore eastern Canada (Williams & Bujak 1977), but in Australia appears to be restricted to the Late Eocene. It has been reported from offshore Tasmania (Haskell & Wilson 1975), the Otway Basin (Cookson & Eisensack 1965) and the western Eucla Basin (Milne 1988).

In summary, a Late Eocene age is likely for the chert dinoflagellate assemblage, although a late Middle Eocene age cannot be entirely discounted.

The palynology of the Dunsborough implement from the Perth Basin was described by Glover *et al.* (1978). Dinoflagellates were extracted from that artifact but the assemblage has little in common with the one described here, and in addition spores and pollen were prominent. An Early to Middle Eocene age was suggested for the Dunsborough implement, and a strong similarity was noted with the microflora described by Cookson & Eisenack (1961) from the Kings Park Formation (this unit in the Rottnest Island Bore is now referred to the Porpoise Bay Formation: see Cockbain & Hocking 1989). The dinoflagellate assemblage described here is quite different from both those assemblages, and displays much stronger affinities with south-eastern Australian assemblages.

The Broke Inlet biface dinoflagellate assemblage is most similar to microfloras described from the Browns Creek Formation of the onshore Otway Basin (Cookson & Eisenack 1965, Stover 1975, A D Partridge pers. comm.) and the Tortachilla Limestone and Blanche Point Formation of the St.Vincent Basin (Harris 1985). These stratigraphic units are age equivalent to the Plantagenet Group in the Bremer Basin according to Harris (1985), and are part of his "Depositional Sequence 3" which is developed right across southern Australia. Thus the similarity between this chert assemblage, which is no doubt derived from the Plantagenet Group, and south-eastern Australian Late Eocene assemblages can be explained by their similar geological setting in relation to the opening Southern Ocean between Australia and Antarctica.

The palynology of the Werillup Formation of the Plantagenet Group has been addressed by Hos (1975) and Stover & Partridge (1982). Hos (1975) noted the presence of dinoflagellates in his material from near Albany but did not document the assemblage. Stover and Partridge (1982) reported that their material from the Fitzgerald River area to the east was nonmarine. In the light of the assemblage described here, future work is necessary to document the dinoflagellates of the Plantagenet Group.

Discussion

The chert artifacts of south-western Australia seem to come from various stratigraphic horizons ranging from Early to Late Eocene (Glover 1984), and are evidently products of the pronounced world-wide process of Eocene silicification, which according to McGowran (1989) reached its peak in the early Middle Eocene.

The Broke Inlet biface artifact has been derived from silicified foraminiferal and bryozoal fine-grained limestone or argillaceous limestone containing a little glauconite, which was similar to protoliths of chert used for the artifacts found along western and southern coastal areas generally. Distance from shore could have accounted for the absence of floral material and clastic mineral debris from the Broke Inlet biface: perhaps also winds were mainly onshore. The large weight of the biface suggests that it may not have been carried far from its place of quarrying.

The environment along the southern coast as Australia drifted northward from Antarctica was probably cooler and more restricted than that along the western coast facing the open Indian Ocean, and it may have affected the mineralogy, diagenesis and palaeontology in ways not yet appreciated. The reason for the abundance of opal in some southerly derived artifacts has not yet been accounted for. Nevertheless, the south-coastal position of the find at Broke Inlet, the implication of short transportation from the weight of the biface, the high opal content, and the palynological similarities to Eocene rocks from the St. Vincent and Otway Basins, combine to indicate derivation from sediments deposited in the Eocene marine channel separating Australia from Antarctica, rather than off the west coast of south-western Australia. The excellent preservation of many of the mineralogical, textural and micropalaeontological features will make the biface an object of useful comparison for other large chert artifacts from the south-west of Western Australia. Fortunately, it is possible with current techniques to extract material for analysis without permanently affecting the external appearance of the artifacts.

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